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(56) Documents Cited
EP 0208310 A

(58) Field of Search
UK CL (Edition K) B3R
INT CL[5] B23K

(54) **Wire bonding control system.**

(57) A wire-bonding process for bonding a wire to a contact surface of an electrical or electronic component, comprises supplying ultrasonic energy to a bonding tool 2 mounted on an ultrasonic transducer 6, the bonding tool being arranged to press the wire against the contact surface of the electrical or electronic component and monitoring the deformation of the wire. The level and duration of the supply of ultrasonic energy and the magnitude of the bonding force are continuously controlled during the bonding process in response to the deformation of the wire, in a closed loop system.

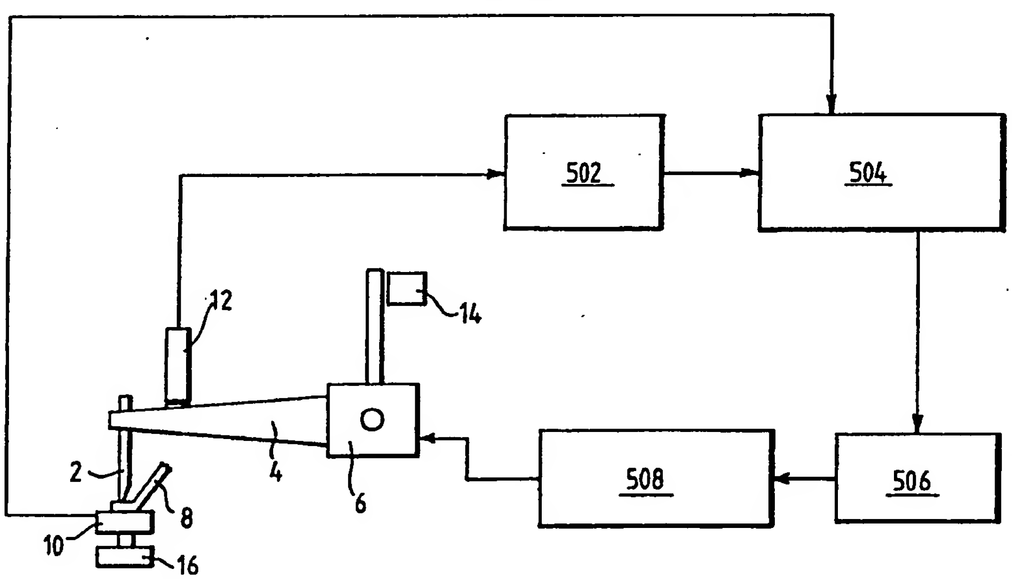

Fig.5.

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The print reflects an assignment of the application under the provisions of Section 30 of the Patents Act 1977.

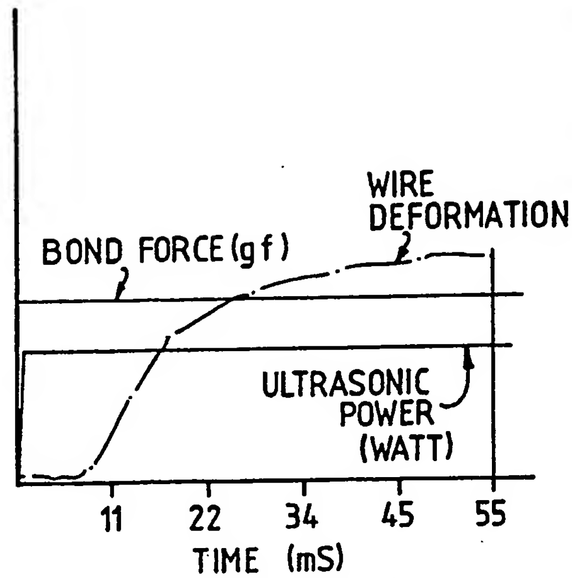

Fig.1.

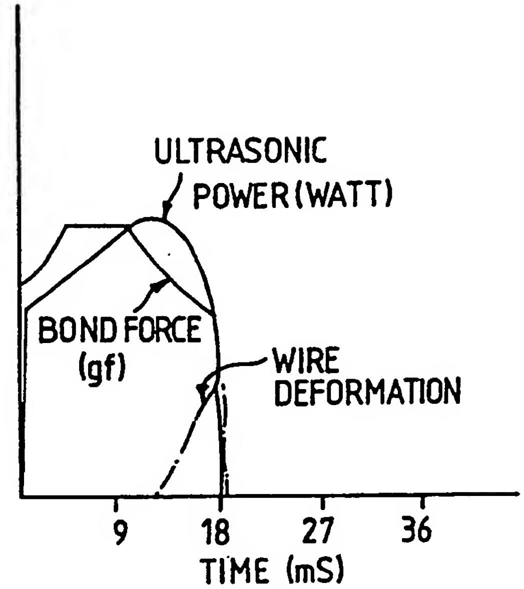

Fig.2.

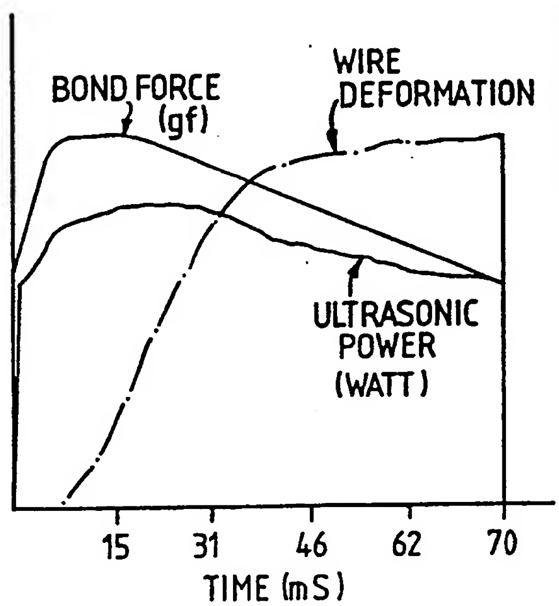

Fig.3.

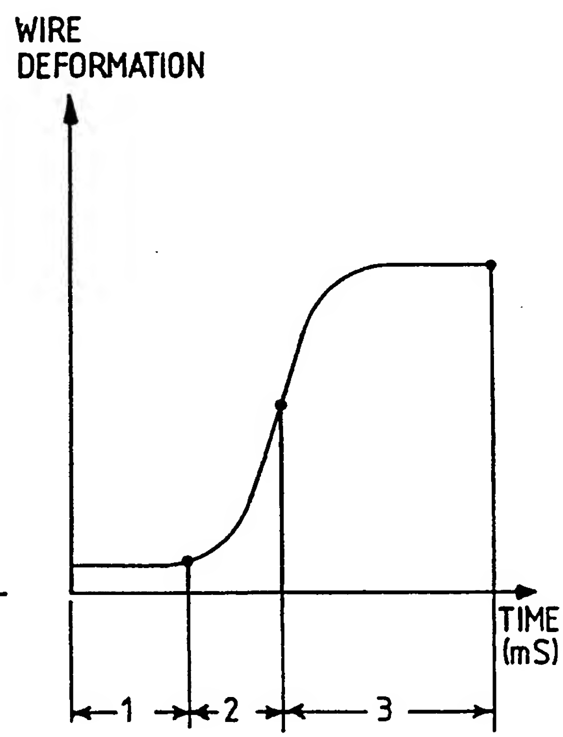

Fig.4.

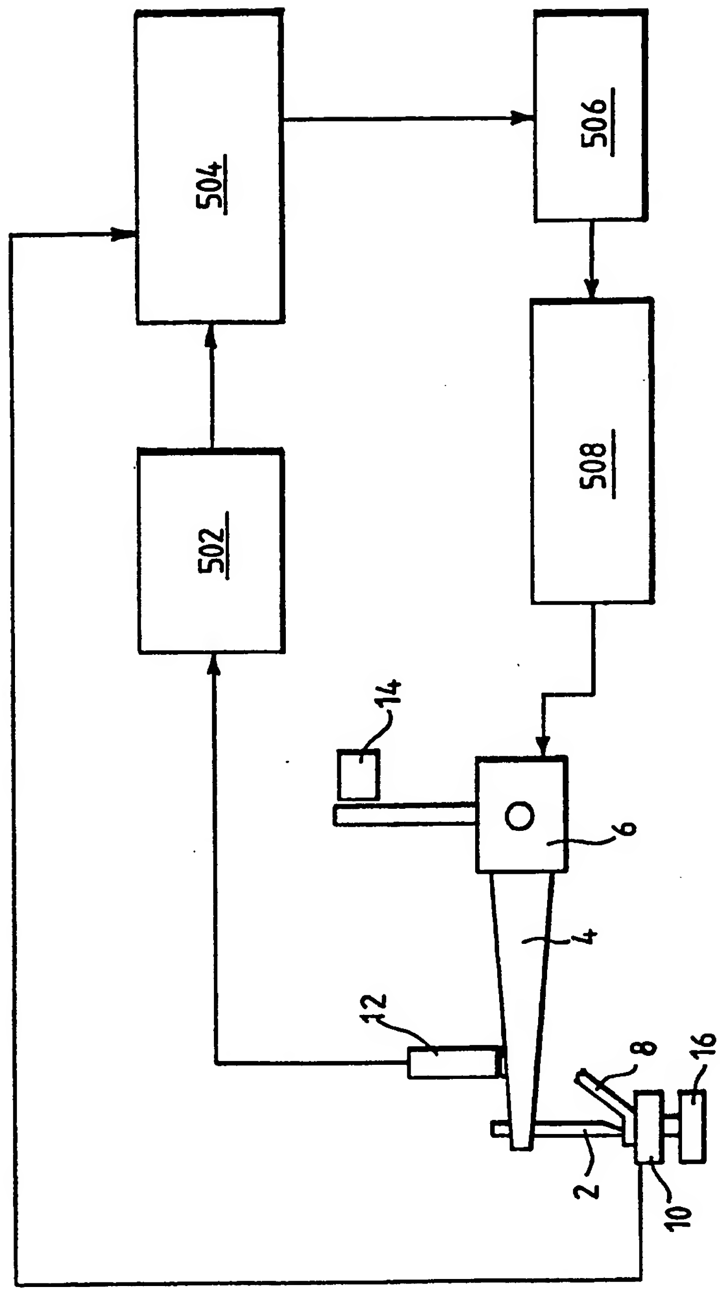

Fig.5.

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CONTROL SYSTEM

The present invention relates to a method for controlling a wire-bonding process, in particular a wedge bonding process using aluminium or gold wire, and to the machine for carrying out that method. The method includes the monitoring, during the bonding process, of the quality of the bond between the wire and the surface to which it is to be bonded.

Wire bonding is the process of making electrical connections in semiconductor components by means of fine metal wire, typically wire with a diameter of from 12 microns to 500 microns. Examples of electrical connections which can be made using wire bonding techniques include connections between the contact surfaces of discrete or integrated chips and the contact leads of their packages, and, in the case of hybrid circuits, the connections between inserted monolithic elements and the film circuit which contains them.

A number of wire bonding techniques have been developed, and one which has been particularly successful is a microwelding technique using ultrasound. An automatic wire bonding apparatus on which such a technique can be operated is described in the present applicants German Patent Application No. P 33 43 738. Aluminium wire, in contact with the contact surface to which it is to be bonded, is moved vigorously in the direction of the surface to which it is to be bonded so that its oxide layer breaks open. The wire is then subjected to pressure, and a permanent junction is created between the two materials. Motion of the wire is generated by an ultrasonic transducer excited by an ultrasonic generator to produce high-frequency mechanical vibrations.

In the particular wire bonding process known as wedge bonding, the ultrasonic energy is supplied at a level depending on the wire size used. The ultrasonic energy is

directed to the aluminium wire by a special tool known as a "wedge". The wire is fed through a guide at the bottom of the wedge. When the wedge with the aluminium wire touches the surface to which the wire is to be bonded, movement is stopped. The wire is pressed down with a small defined force, known as the bonding force or weight, and the wire is slightly deformed. This small deformation is known as the "pre-deformation". Ultrasonic energy is now switched on, and the welding process starts. During this time, the diameter of the aluminium wire is reduced by a few microns, the actual reduction depending on the size, physical properties and the precise chemical nature of the wire.

It is important in an automatic wire bonding apparatus to have as much control as possible over the process, and to be able to determine whether or not a bond has been successfully made. In particular, it is important to be able to ascertain when the wedge with the aluminium wire touches the surface to which the wire is to be bonded, so that movement of the wedge can be stopped. It would also be very useful for the operator of the wire bonding apparatus to ascertain whether a bond has been successfully made at the time of bonding rather than during a subsequent test routine. Because of the very rapid throughput of an automatic wire bonding apparatus, it would be advantageous if the bonding could be monitored immediately at the time of bonding, so that after the formation of an unsatisfactory bond the process can be stopped and the bonding conditions checked to prevent the production of a large number of unsatisfactory bonds, with the consequent wastage of time and expensive components and materials.

Most wire bonding machines currently in commercial use are only able to check whether a successful bond has been made after bonding is completed, using a test known as the loop-pull test. This test is typically used as a destructive test method in which samples are tested to destruction by pulling the loop between two bonds and noting

the breaking force which is required, and the point at which the break occurs. In general, bonding is considered to be satisfactory if the wire breaks at the point approximately equidistant between the two bonds at which the force is applied; if the break occurs at the bond itself, with the wire lifting away from the surface to which it was supposed to be bonded, then this is due to the bonding being insufficient. If, alternatively, the wire breaks close to the bond, at the so-called heel, then this is generally the result of over-bonding, when too much pressure or too much ultrasonic energy has been applied to the wire, and the wire has been too highly deformed.

A number of methods have been proposed to check at the time of bonding whether or not a successful bond has been produced, including the method carried out using the apparatus described in the present applicants European Patent Application No. 0 368 533. The apparatus claimed in that specification comprises a bonding head comprising a bonding tool mounted on an ultrasonic transducer, a bonding tip of the tool being arranged, in the operation of the machine, to press aluminium wire against the contact surface of an electronic or electrical component, the wire being drawn from a suitable wire supply, and a wire clamp by which the wire drawn from the wire supply may be clamped, the wire clamp being movable backward and forward generally in the direction in which the wire is fed appropriately to position the free end of wire drawn from the spool after completion of a bonding operation, characterised in that the automatic wire-bonding apparatus further comprises means for monitoring, during bonding, the quality of the bond formed between the wire and the surface to which it is to be bonded, by identifying those bonds which do not fall within predetermined maximum and minimum values for deformation of the wire due to ultrasonic excitation.

In the present applicants co-pending UK patent application No. 9123047.4, there is described and claimed a

method for carrying out a wire-bonding process for bonding a wire to a contact surface of an electrical or electronic component, which process comprises supplying ultrasonic energy to a bonding tool mounted on an ultrasonic transducer, the bonding tool being arranged to press the wire against the contact surface of the electrical or electronic component and monitoring the deformation of the wire, characterised in that the level and duration of the supply of ultrasonic energy is continuously controlled during the bonding process in response to the deformation of the wire.

That application further describes and claims an automatic wire bonding apparatus which apparatus comprises a bonding head comprising a bonding tool mounted on an ultrasonic transducer, a bonding tip of the tool being arranged, in the operation of the machine, to press aluminium wire against the contact surface of an electronic or electrical component, the wire being drawn from a suitable wire supply and a sensor for determining the change in position of the bonding wedge during the bonding process, characterised in that the automatic wire bonding apparatus further comprises means for controlling the supply of energy to the ultrasonic transducer in response to the output of the sensor for determining the change in position of the wedge during the bonding process.

Most of the known systems control the bonding process by means of controlling the time at which a constant level of ultrasonic energy is supplied to the bond. This has the effect that the time for which energy is supplied and the level of energy supplied are both set for what can be considered as a 'worst case' bond, whereas for many bonds, both the quality of the bond and the efficiency of the bonding process, both in terms of the time taken and the energy consumed would be improved by more accurate control of the ultrasonic energy supply.

It is an object of the present invention to provide a method of controlling a wire bonding process, in particular a wedge bonding process using aluminium wire, in which the above disadvantages are reduced or substantially obviated. It is a further object of the present invention to provide a machine for carrying out that method.

The invention provides a method for carrying out a wire-bonding process for bonding a wire to a contact surface of an electrical or electronic component, which process comprises supplying ultrasonic energy to a bonding tool mounted on an ultrasonic transducer, the bonding tool being arranged to press the wire against the contact surface of the electrical or electronic component and monitoring the deformation of the wire, characterised in that the level and duration of the supply of ultrasonic energy and the magnitude of the bonding force are continuously controlled during the bonding process in response to the deformation of the wire.

The invention further provides an automatic wire bonding apparatus which apparatus comprises a bonding head comprising a bonding tool mounted on an ultrasonic transducer, a bonding tip of the tool being arranged, in the operation of the machine, to press aluminium wire against the contact surface of an electronic or electrical component, the wire being drawn from a suitable wire supply, and a sensor for determining the change in position of the bonding wedge during the bonding process, characterised in that the automatic wire bonding apparatus further comprises means for controlling the supply of energy to the ultrasonic transducer and the magnitude of the bonding force in response to the output of the sensor, for determining the change in position of the wedge during the bonding process.

It has now been appreciated that the bonding process is not, as has previously been assumed, a single stage process, but is in fact a two or three-stage process, each of which stages is advantageously carried out with the level of

ultrasonic energy and the magnitude of the bonding force being supplied at that stage being specifically determined for that stage. In particular, it has been determined that the bonding process comprises a first stage, in which the surfaces of the wire and the substrate to which it is to be bonded are cleaned; a second stage in which welding between the wire and the substrate takes place, and, in the case of thick wires, there is a third stage during which high temperature tempering of the bond area takes place by means of ultrasonic energy.

It has further been observed that each of these stages is advantageously carried out at a different energy level and bonding force, which can be empirically determined and controlled during the bonding process. It is in general found that the first, or cleaning, stage requires a relatively high energy level and relatively high bond weight and takes place relatively rapidly; the second, or welding, stage requires a lower energy level and lower bond weight and the third, tempering stage, where this occurs, requires an energy level and bond weight which varies depending on the particular bond.

While it is generally found that the energy levels and bond weight required change as stated above, this is not necessarily the case and it is a particular advantage of the process according to the present invention that the bonding parameters are determined for each individual bond and optimised for that bond.

Even successive bonds formed using the same wire and the same substrate may differ widely in their energy and bond weight requirements, and by constantly monitoring the bonding process according to the invention, bonds of a consistent high quality can be achieved with high efficiency, independent of any variations in the bonding conditions.

The system according to the invention is thus an in-line closed loop system. An embodiment of the process

according to the invention and an embodiment of an automatic wire bonding apparatus suitable for carrying out such a process will now be described with reference to the accompanying drawings of which

Figure 1 is a graph showing wire deformation against time using constant ultrasonic energy and constant bond weight (prior art);

Figure 2 is a graph showing wire deformation against time using ultrasonic energy and bond weight controlled according to wire deformation (for an aluminium bonding wire having a thickness of 25 micron);

Figure 3 is a graph showing wire deformation against time using ultrasonic energy and bond weight controlled according to wire deformation (for an aluminium wire having a thickness of 250 micron);

Figure 4 is a graph showing the three stages in the wire bonding process and

Figure 5 is a block diagram of an embodiment of an automatic wire bonding apparatus.

In a prior art bonding process as shown in Figure 1, ultrasonic energy is supplied at a constant level and bond weight throughout the bonding process. There is an initial period, of approximately 9 milliseconds in which there is little deformation of the wire, followed by a second period during which the deformation of the wire increases sharply and a third period in which there is virtually no further deformation. According to the prior art control systems, a satisfactory bond has been formed because the deformation falls within the preset limits for minimum and maximum permissible wire deformation. However, it is clear from the graph that the energy supplied after approximately 34 milliseconds bonding time has not been usefully used in bonding and there has thus been wastage both of energy and operating time. However, according to the prior art it has not been possible to reduce the bonding time for an individual bond since later bonds between the same wire and

the same contact surface might require a longer excitation time.

In Figure 2, a bonding process using ultrasonic energy and bond weight controlled according to wire deformation is shown. The wire being bonded is a thin wire, having a thickness of 25 micron, and the bonding is a two-stage process.

In the first stage, energy is supplied at a relatively high level, with a relatively high bond weight and there is almost no deformation of the wire. This is because during this stage, for the first approximately 12 milliseconds of the bonding process, the surface of the wire and the contact surface are being cleaned of surface contamination. This contamination generally takes the form of surface oxidation and may also comprise organic contamination.

As can be seen from Figure 2, when cleaning is complete, there is a sharp increase in deformation as the second stage is initiated. During the second stage, the level of the ultrasonic energy and the bond weight are reduced and when the deformation of the wire reaches a predetermined value, the energy is switched off since the bond is completed.

In Figure 3, a second bonding process using ultrasonic energy and bond weight controlled according to wire deformation is shown. The wire being bonded is a thick wire, having a thickness of 250 micron, and the bonding is a three-stage process. The first two stages of cleaning and welding correspond to the first two stages of the process shown in Figure 2. There is however a third stage during which energy continues to be supplied to the bond, according to a predetermined curve, in order to heat the bond and allow tempering of the bond at elevated temperature.

Figure 4 shows diagrammatically the three stages of the bonding process for a relatively thick wire, having a thickness greater than approximately 100 microns.

In the first stage, the surface of the wire and the contact surface to which it is to be bonded are subjected to a cleaning process and there is relatively little if any deformation of the wire. During the second stage, there is rapid deformation of the wire as the weld is formed. During the third stage, the rate of deformation of the wire reduces rapidly as the weld is completed and tempering takes place.

An embodiment of an automatic wire bonding apparatus is shown diagrammatically in Figure 5.

The automatic wire bonding machine comprises a bonding wedge 2 which is attached to a horn 4 of an ultrasonic vibration transducer 6. Wire 8 for bonding to a component 10 is fed from a wire spool (not shown) in known manner. A deformation sensor 12 is connected in a closed loop system to a wire deformation measuring system 502 which is connected via a processor 504 to an ultrasonic regulator 506 which is itself connected to an ultrasonic power generator 508 which drives the transducer 6.

A bond force regulator 14 is attached to the horn 4 of the ultrasonic vibration transducer 6. A piezo table 16 is positioned below the component 10 to measure bond force.

In operation, data from the deformation sensor 12 is fed via the wire deformation measuring system 502 to the processor 504 where the process is continually monitored and the required level of ultrasonic energy calculated. Data on the calculated level is then used to control the ultrasonic generator 508 by means of the ultrasonic regulator 506. In a similar manner, data from the piezo table 16 is used to control the bond force regulator 14 and deliver the information to processor 504.

The deformation sensor 12 and wire deformation measuring system 502 may be any suitable deformation system such as an electronic system or an optical system, for example a laser system.

CLAIMS:

1. A method for carrying out a wire-bonding process for bonding a wire to a contact surface of an electrical or electronic component, which process comprises supplying ultrasonic energy to a bonding tool mounted on an ultrasonic transducer, the bonding tool being arranged to press the wire against the contact surface of the electrical or electronic component and monitoring the deformation of the wire, characterised in that the level and duration of the supply of ultrasonic energy and the magnitude of the bonding force are continuously controlled during the bonding process in response to the deformation of the wire.

2. A method according to claim 1 in which the wire has a thickness of less than 100 microns, and the process is carried out as a two-stage process in the first stage of which ultrasonic energy is supplied in order to clean the surface of the wire and the contact surface to which it is to be bonded and a second stage in which ultrasonic energy is supplied in order to form a weld between the wire and the contact surface.

3. A method according to claim 1 in which the wire has a thickness of greater than 100 microns, and the process is carried out as a three-stage process in the first stage of which ultrasonic energy is supplied in order to clean the surface of the wire and the contact surface to which it is to be bonded, a second stage in which ultrasonic energy is supplied in order to form a weld between the wire and the contact surface and a third stage in which the bond between the wire and the contact surface is tempered at elevated temperature.

4. An automatic wire bonding apparatus which apparatus comprises a bonding head comprising a bonding tool mounted on an ultrasonic transducer, a bonding tip of the tool being arranged, in the operation of the machine, to press aluminium wire against the contact surface of an electronic or electrical component, the wire being drawn from a suitable wire supply and a sensor for determining the change in position of the bonding wedge during the bonding process, characterised in that the automatic wire bonding apparatus further comprises means for controlling the supply of energy to the ultrasonic transducer and the magnitude of the bonding force in response to the output of the sensor for determining the change in position of the wedge during the bonding process.

5. A process substantially as herein described with reference to the accompanying drawings.

6. An automatic bonding apparatus substantially as herein described with reference to the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number

GB 9219029.7

Relevant Technical fields

(i) UK Cl (Edition K) B3R

(ii) Int Cl (Edition 5) B23K

Databases (see over)

(i) UK Patent Office

(ii)

Search Examiner

D N P BUTTERS

Date of Search

2 DECEMBER 1992

Documents considered relevant following a search in respect of claims 1-6

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	EP 0208310 (SIEMENS) whole document	1-4

SF2(p) DT - doc99\fil000494

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

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P: Document published on or after the declared priority date but before the filing date of the present application.

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